In-Situ Ultrasonic Characterization Of Patterns of Sediment Surface Roughness and Subsurface Volume Inhomogeneities

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LONG TERM GOALS

Our goal is to take a mature technology that successfully images surface and sub-surface biogenic structure non-invasively in the laboratory (ultrasound) and convert the technology for use in marine systems in the field. We intend to convert one of our existing ultrasound machines (ALOKA SSD-500) to a field-deployable unit by constructing a pressure housing for it waterproof to 50 m water depth. We will deploy the unit in the field with the use of divers during the summer in the sediments of Narragansett Bay, RI. Our research goal during field deployments is to determine patterns of sediment surface roughness to 1mm horizontal and vertical resolution and to determine the abundance of volume inhomogeneities (tubes, voids) in the upper 3 – 4 cm. We intend to sample before and after a sediment resuspension event, our hypothesis being that effects on subsurface volume inhomogeneities will be greater than effects on surface roughness patterns, similar to results of our laboratory studies. Based on laboratory results, simulated disturbance in the laboratory leads to the disappearance of subsurface volume inhomogeneities and a lesser smoothing of surface roughness features. The use of commercial ultrasonic sensors allows us to examine temporal patterns in biogenic structure and roughness on fine spatial scales (mm) without invasive disturbance.

OBJECTIVES

Our major objective is to take the technology that has worked so well for us in laboratory situations and convert an ultrasound machine to a field-deployable unit. We will convert our ALOKA SSD-500 to a field-deployable unit by constructing a pressure housing containing the ultrasound machine, battery packs and an inverter/charger, along with a VCR for data storage. We will deploy this unit with divers in Narragansett Bay, RI and attempt to sample before and after a sediment resuspension event to assess the impact on surface roughness compared to subsurface volume inhomogeneities.

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APPROACH

We will modify our existing ALOKA SSD-500 ultrasound machine for seagoing use. The Ocean Engineering technical staff under the direct supervision of Miller will construct a pressure-housing waterproof to 50 m. Since the plans for the field unit are for diver deployments, attention will be paid to streamlining and buoyancy considerations. Our 3.5 MHz ultrasonic probe will be integrated permanently into a port in the housing. Additional material for insertion into the pressure housing are a VHS VCR, battery and inverter/charger to power both the ultrasound machine and the video recorder. The probe will be located ventrally on the housing.

Initial testing of housing integrity and system function will be conducted in the test-tank facilities of the Dept. of Ocean Engineering at URI. After passing system integrity at this level, the unit will be deployed by divers in Narragansett Bay, RI in the summer of 1999. Our major goal is to take images of the sediment before and after a sediment resuspension event. Random ultrasound images of the sediment surface and sub-surface structure will be collected within an experimental area near Dutch Island in Narragansett Bay, at a depth of approximately 7 m. Images of a variety of sediment structural types (mud, sand, shelly) will be obtained. After being captured on videotape, ultrasound images will be analyzed on the existing computer facilities of the PI (video capture capability and image analysis capability). Surface roughness will be measured using MATLAB programs that digitize the sediment surface. Proportion of volume inhomogeneities will be measured on the images using skeletalization algorithms. Patterns will then be compared between the two sampling dates.

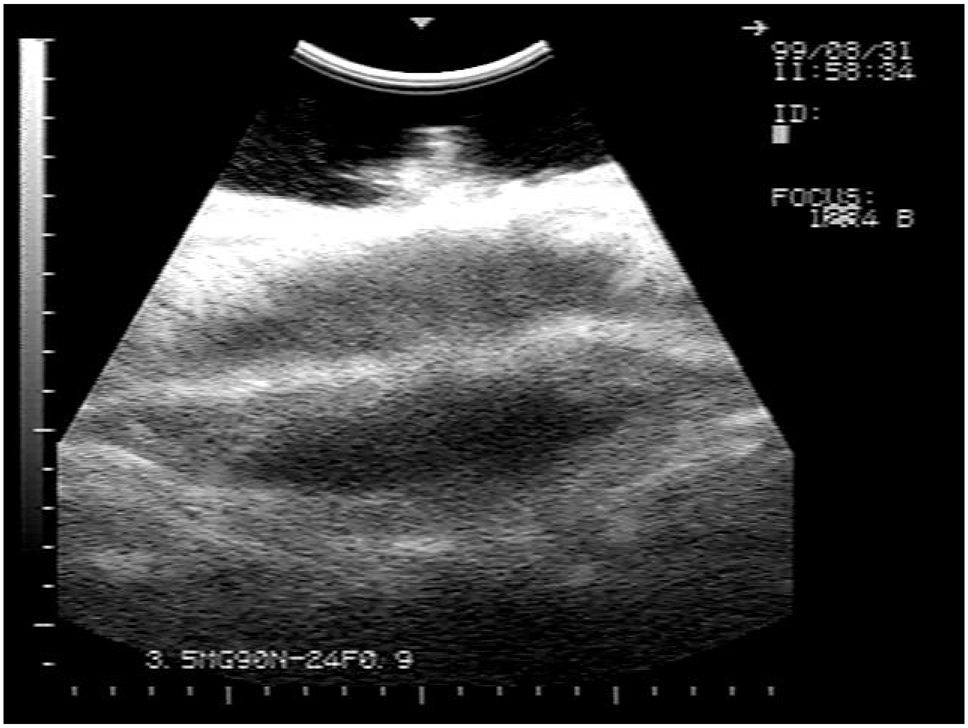
WORK COMPLETED

The ALOKA SSD-500 was successfully converted to ocean-going use. An aluminum pressure housing (sled-type) was created containing the ultrasound machine, VCR, battery and inverter/charger. The housing was constructed of welded ¼” aluminum plate with ½” thick lexan windows for internal access. Final size was 32” long by 21” high by 16” wide (Fig. 1). After extensive testing in the Ocean Engineering tank facilities, the unit was deployed in the field (Dutch Harbor, RI) on August 23, 1999. It was subsequently deployed on August 31, 1999, after the passage of a strong frontal system. Strong northeasterly winds caused significant sediment resuspension in the Bay during the passage of this frontal system. The unit was deployed from an 80 foot research vessel via A-frame winch, released and handled by 2 divers with a small tender boat watching the divers. Unit activity lasted 30 minutes in the water, obtaining images of a variety of sediment types in the same area before and after the passage of the frontal system. Images were analyzed using MATLAB and skeletalization algorithms for comparison to bottom type and sampling date.

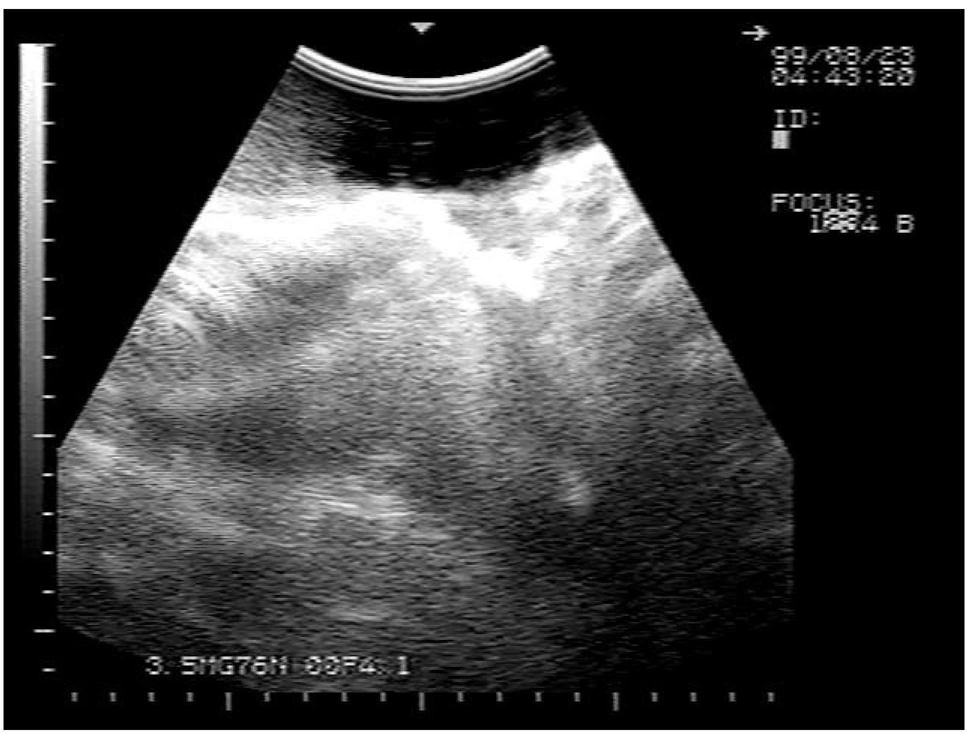
RESULTS

We were extremely happy with the performance of our seagoing unit in the field tests. With addition of appropriate weight, the unit was neutrally buoyant in the field and easily handled by the divers. Good video records were obtained of bottom topography on both sampling dates (Fig. 2 & 3).

1. Ultrasound machine in pressure housing (Galileo) alongside the PI in Dutch Harbor, RI, before field sampling.



2. Ultrasound image in diatom mat area, August 23, 1999. Image is essentially cross section through sediment. Note presence of animal burrows in upper left of image. Tick marks are 1 cm.



3. Ultrasound image in shelly sand area, August 23, 1999. Note sharp white reflections caused by shell debris.

A variety of sediment types were sampled for this study, ranging from mussel beds to smooth muddy bottoms. Patterns of sediment surface roughness were easily taken from the video records, and ranged from a RMS-height of 0.06 +/- 0.002 (n=5) for the mud site to 0.73 +/- 0.11 for the mussel bed bottom. Interestingly, RMS-height did not vary with sampling date, indicating that the strong resuspension event in the area had little effect on bottom roughness. Subsurface volume discontinuities were only visible in the diatom mat and mud areas, since the high reflectivity in the shelly sand areas and areas containing mussels masked these features. Void volume ranged from 6-21% in the upper 4 cm of sediment (n=6). Surface roughness features could be mapped with 1mm horizontal and vertical resolution and subsurface structure could be mapped with similar resolution to 3 – 4 cm below the sediment surface when visible.

IMPACT

This research has demonstrated the utility of examining benthic structure in the field without the traditional disturbance caused by coring. As such, the use of this technology allows us to make a major breakthrough in the analysis of sediment systems.

TRANSITIONS

We have demonstrated the use of ultrasound in examining patterns of benthic structure in the field and laboratory over the past 3 years. This is a technology that works and is available to the scientific community at large.

RELATIONSHIP TO OTHER PROJECTS

None.